Knowledge modelling framework

Towards user-centered medical services delivery in the emergency context

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***Abstract*—This paper presents a conceptual knowledge modelling framework that aims at facilitating the decision support functions in the emergency management domain. The EDXL-based group of standards is the most complete approach to address emergency information sharing and data exchange across various actors involved in the process of disaster management. Therefore, it is selected as the central basis of knowledge models to utilise and extend with semantic information models towards enhanced knowledge-level interoperability and more efficient decision making.**

***Keywords*—decision support; EDXL; knowledge modelling; semantic technology**

I. Introduction

Successful management of mass casualty incidents or medical surges to healthcare systems requires adequate preparation to prevent, respond, and rapidly recover. Effective response to large numbers of same-type injuries typical for disasters can only be achieved by good communication between emergency service providers to ensure immediate and simultaneous medical intervention and means of support such as ambulances, medical supplies, transportation, specialists, room, diagnostic equipment and others. In particular the link between pre-hospital and hospital service organisation is a critical factor for success. While a number of research prototypes of applications to assist communication and information management in the aftermath of disasters have been developed, a recent review of such applications indicates that still most of the applications rely on paper-based methods to collate and transmit information [1]. The proper technology-based Decision Support System (DSS) can considerably improve the preparedness and interoperability of medical services during an emergency.

While the study of DSS comprises a well-established field growing since the mid-seventies, several research surveys have pointed out that DSS technology (and in particular when related to the security, crisis management, and planning domains) still needs enhancements in various aspects [2]. The need for more flexible information integration means is recognised, such as to link together the objective measurements obtained from sensors with reports from human actors. Information filtering of large amounts of data typical for emergency response applications would require more meaningful data representation mechanisms and a clear allocation of the information to specific roles and types of actors. Interpretation of available data sets would be aided by online and offline mechanisms allowing work with partial data and extension with new and missing data. Decision support points in the response process need linking. DSS models' interoperability is still in its infancy.

The authors of the present paper believe that recent advances in semantic technologies can be utilised in DSSs and bring additional value to enhance existing practices in the field, as well as, address the challenges discussed above. Semantics-based tools may facilitate various knowledge management related tasks, such as information modelling and heterogeneous information integration, knowledge reasoning, knowledge representation, as well as knowledge annotation and discovery. There is an effort made by the research community to deliver domain specific ontologies to tackle these challenges. A good overview is given by researchers from Aston and Warwick Business Schools [3]. As pointed out by the authors of the survey, among the ontologies designed and published in the research papers and reports, very few are formally represented and publicly accessible. In addition, they are disconnected from the existing standard data models, data-exchange formats, and protocols related to emergency management. Another challenge related to the domain-specific ontologies is associated with their evolve-ability, extensibility, and maintainability. Other, more widely adopted approaches, such as the ones based on the recently introduced concept of Open Linked Data [4], may sound more practical also in terms of adopting semantic technologies by the third-party service providers.

The semantics-based knowledge modelling framework presented in this paper, aims at addressing the shortcomings and challenges identified above. The requirements to knowledge management functions, which are realised by developing and analysing defined scenarios and use-cases, are presented in Section II. In order to identify the existing standards that should be taken into account in the context of knowledge representation, research on relevant standardisation efforts and initiatives has been conducted and overviewed in Section III. The proposed knowledge modelling framework is discussed in Section IV. Section V, then, concludes the research.

II. Knowledge Management Requirements

A. User-driven extraction of scenarios and use-cases

Before studying specifically the decision support aspects, an approach having the emergency response actors in the center of the research had been adopted for the collection and analysis of general emergency response user needs. The utilised methods involved literature and clinical practice reviews, face-to-face interviews with stakeholders (e.g. the London Ambulance Service, the Vienna Red Cross, the Sofia Military Medical Academy), focus-groups and workshops with stakeholders from several EU countries, email-interviews, as well as online discussions and targeted questionnaires. At the early stages of the requirements' analysis, the need to structure the emergency response domain had been revealed, so as to manage and properly codify the users' needs. This led to the codification of the principal five spaces (and phases) in which actions directly related to medical emergency response occur. Fig. 1 illustrates these five phases, which formed the foundation for the subsequent analysis of user requirements. The five phases are summarised as: (1) Initial Alert: the phase where the initial alert is being managed, usually a 112 call center/Public Safety Answering Point (PSAP); (2) Emergency Medical Service (EMS) on the Way: the phase in which an EMS team, dispatched to emergency event's location, performs its tasks (usually an ambulance en route to location); (3) Field Management: the "field", i.e. the event's site where the people requiring urgent medical help (victims) are located; (4) Transport: the phase in which an EMS team, that takes a victim/patient to a First Receiver, performs its tasks (usually an ambulance en route to a First Receiver); (5) First Receive: the phase in which the First Receiver prepares for and later takes over the care of the patient (usually a hospital or a medical shelter).

The emergency responders working in each of these five phases/spaces have sets of patient-related tasks which are the same, irrespective of country or type of incident. These are the tasks that form the basis for the generic set of requirements for technology and decision support. The more the actions across the spaces are interlinked by effective communication technology and the more provisions for mutual visibility, early situational awareness, and decision support are provided, the more the phases are enabled to run in parallel, therefore saving time and becoming more effective in saving lives. Each of the five phases was then described based on a specific set of "needs" of involved actors and organisations.

An extended list of small and large realistic emergency event scenarios has been then described, validating and providing justification of the needs. Three of these emergency response scenarios are presented, indicatively, in Table I, so as to support the understanding of the applicability of the proposed knowledge modelling framework.

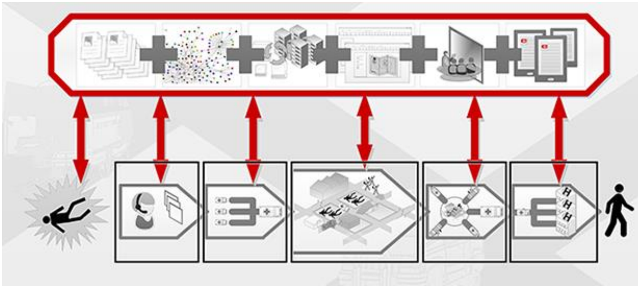

Fig. 1. The five phases-spaces of the medical emergency pipeline

TABLE I. Indicative Scenarios and Needs

Scenario 1: *"Initial Alert" Phase: "Decision and Order of Initial Resource Deployment"*
Six school kids and their teacher get lost in the forest in November, for 24 hours. The school has a no-cell phone-policy and the teacher's phone battery has gone down very fast unexpectedly. The next day, still walking, they see a river and decide to cross it because they believe that the river is close to the main road. The river is not particularly deep but they all get wet and feel cold. One of the kids becomes really unwell and has to be carried. Finally they reach the road and stop a car and the driver calls 112. The PSAP decides to dispatch vehicles carrying resources for hypothermia treatment (e.g. space blankets, warm fluids, etc.) for 7 persons.
Discussion: Mapping the situation to the appropriate types of resources is of vital importance. The dispatched resources should ideally meet the needs of the incident. Being able to use some form of guidance to the projected resource requirements to manage the incident, will enable the PSAP to respond adequately and timely, which will positively affect health outcomes of the victims.
Scenario 2: *"EMS on the Way" Phase: "Communication between PSAP and EMS vehicle"*
Large-scale emergency: In a High School with large park-like grounds there has been a terrorist attack, with students collapsed in several school locations on the grounds. A teacher manages to call for ambulances. Due to the severity of the situation, the ambulances need to arrive within minutes in order for some students to have a chance to be saved. Unfortunately the school grounds front and back entrances are reachable via two narrow paths in a newly built area, not clearly visible from the regular roads and not easy to recognise as a school's access road. The ambulances' drivers have difficulty finding the entrance and then the exact location of the victims within the grounds. The drivers wish they had an automatic way to be able to locate the students.
Discussion: Being able to obtain updated situational awareness information online, enables timely response.
Scenario 3: *"Field Management" Phase: "Dynamic Situation Assessment"*
EMS arrives at the scene of a train accident where carriages are

spread all over the place. It is unclear how many carriages are derailed, since the area is large. The EMS commander needs to be able to see and receive all the information on the situation in order to make proper decisions on command and control. He has a piece of paper where he draws a map of the area, which he updates with all the latest information. The drawing is a result of what he can see and what his colleagues report to him. If he had access to a satellite map, things would have been different; he would have been able to at least better grasp the geography of the location with its hills and gorges.

Discussion: Having access to an online operational map which links and visualises several aspects of the emergency incident, greatly improves decision support. Values describing size of incident, type, mechanism, hazards, safety, casualties, etc., may change dynamically and grasping all the changes plus keeping track of all the new information coming in is not easy, particularly under stress.

The analysis of scenarios as the ones presented, formed the basis for the extraction of the requirements for knowledge management to address the needs of decision support.

B. Addressing the Needs of Decision Support through Knowledge Management

As shown in the presented scenarios, knowledge is largely associated with situation awareness in the emergency response domain, which derives from good quality and a sufficient quantity of timely, accurate, and reliable information, necessary to support the decision makers [5]. The approach to address the situation awareness is to identify the requirements and critical information sources in dynamic situations and to provide the support means to capture this critical information. In addition, apart from real-time information coming from the field, the availability of supportive knowledge in the form of historical documents, previous decisions made in similar situations, predefined instruction- and guideline- documents are important to support the decision making and coordination tasks. Moreover, as various actors (and accordingly various heterogeneous information infrastructures) are involved as information providers in the disaster emergency management context, there is a demand for the means to support the interoperability among different information sources towards their access and information reuse. Last but not least, in order to make the collected information and knowledge useful, it needs to be indexed, categorised, and inter-linked with other related information and knowledge. The scope of knowledge management in this work can be formulated as: i) providing support for domain-specific information and knowledge sources capturing, modelling and searching, ii) providing support for the transformation from data to knowledge, and iii) providing support for data and information interoperability.

In order to better control the knowledge management requirements revealed from the user-driven scenarios and the subsequent analysis, a categorisation, i.e., abstraction of scenarios' use cases has been adopted as follows:

1. Locatable components: A key piece of knowledge required to be kept by a system offering coordination and decision support, are the actual locatable "resources" that are managed through the process. These can be responders, vehicles, patients, bystanders, equipment – anyone and anything within the high priority list, the location and position of which adds value in the process of the response. In fact, an emergency event forms a specific demand for resources, while the response to the event is the deployment (supply) of the appropriate resources to address the demand.

2. *Transmittable patient status parameters*: Patient's location and triage status, but also the real-time physiological parameters and a basic list of needs (e.g., burns, head trauma) for allocation purposes.

3. *The emergency incident e-Form:* Comprises all the information about the incident from the moment of information coming in to the PSAP (alert call), through to field management, through to management in the vehicle to first receiver. It needs to be automatically collected in one space, using all the heterogeneous sensor and human data entries that are available – e.g. computer entry at PSAP, triage status, vital sign recording, basic treatment, needs categorisation, etc., in order to maximise situational awareness. The form may contain information as: type of incident, size, hazards, access, number of victims, degree of urgency, various mechanisms, etc.

4. *The Joint operational map*: Area and component visualisation in the most simplistic and reliable way, allowing different views to different users. Examine also how citizens' resilience can be incorporated into providing information, including the potential contribution from social networks.

III. State-of-Art on Domain Specific Knowledge standards

This Section presents an overview of the main standards that apply to the emergency management field, so as to identify what should be considered in the context of emergency management knowledge representation.

A. Emergency Management Information Standards

1) The OASIS EDXL-based knowledge models: EDXL aims at facilitating emergency information sharing and data exchange across organisations of different professions that provide emergency response and management services [6]. The current set of EDXL Standards includes:

a) EDXL Common Alerting Protocol (EDXL-CAP): CAP provides an open, non-proprietary digital message format for all types of alerts and notifications. It provides means for a single point of activation of all kinds of alerting systems.

b) EDXL Distribution Element (EDXL-DE): It facilitates the routing of any properly formatted emergency message to recipients. The DE is a form of "container", providing the information to route "payload" message sets, e.g. Alerts or Resource Messages, by including key routing information such as distribution type, geography, incident, and sender/recipient IDs.

c) EDXL Resource Messaging (EDXL-RM): it provides a set of standard formats for XML emergency response messages; these Resource Messages are specifically designed as payloads of EDXL-DE-routed messages. The combination of EDXL-DE and EDXL-RM intends to expedite all activities associated with resources needed to respond and adapt to emergency incidents.

d) EDXL Hospital Availability Exchange (EDXL-HAVE): it specifies an XML document format that allows the communication of the status, services, and resources of a hospital, i.e., bed capacity and availability, emergency department status, available service coverage, and the status of a hospital's facility and operations.

e) EDXL Situation Reporting (EDXL-SitRep): it provides a set of standard formats for XML emergency response messages specifically aimed at transmitting timely situation reports. It defines five separate report types to support incident command decision making across the emergency incident life-cycle, including preparedness, pre-staging of resources, initial, ongoing response, recovery and demobilisation/release of resources and after-action analysis to identify needed improvements in ongoing preparedness.

f) EDXL Tracking Emergency Patients (EDXL-TEP): it is an XML messaging standard for exchange of emergency patient and tracking information during patient encounter through admission or release.

2) Tsunami Warning Markup Language and Cyclone Warning Markup Language: these standard-based languages aim to define structured semantic data models for tsunami bulletins and cyclone advices, respectively [7]. They use selected concepts from the Geography Markup Language (GML), e.g., GML points for describing locations, to facilitate integration with mapping and geospatial systems. They can be used in conjunction with standards that support the exchange of information in emergency situations, e.g. EDXL-DE and CAP.

3) IEEE 1512 – Family of Standards for Incident Management Message Sets: it supports the exchange of incident-related data between transportation, public safety, and other responding agencies [8]. It consists of a base standard and three companion volumes, which define message sets for use in traffic-related, public safety, and hazardous material incident management.

B. Patient and Victim Information Tracking Standards

1) ASTM Continuity of Care Record (CCR): CCR is a core data set of the most relevant administrative, demographic, and clinical information facts about a patient's healthcare, covering one or more healthcare encounters [9].

2) HL7 Continuity of Care Document (CCD): The CCD specification is an XML-based markup standard intended to specify the encoding, structure, and semantics of a patient summary clinical document for exchange [10].

3) Emergency Responder Electronic Health Record (ER-EHR): The ER-EHR Interoperability Specification of the Healthcare Information Technology Standards Panel (HITSP) is a U.S. national presentation of how information can be collected and exchanged during the entire emergency medical Episode of Care, from the first notification to an emergency response organisation through the completion of the last encounter [11].

4) Public Health Information Network (PHIN) Messaging Standards: A PHIN compliant messaging allows for the consistent exchange of response, health, and disease tracking data between public health and healthcare partners [12].

5) Vehicular Emergency Data Set (VEDS): VEDS provides critical data elements and the schema set needed to facilitate an efficient emergency response to vehicular emergency incidents [13].

C. Emergency Medical Services Data and Exchange Standards

1) Data Elements for Emergency Department Systems (DEEDS): it is a comprehensive description of data elements common in emergency department information systems [14]. It defines important data points (e.g. time of arrival, value of first blood pressure) and how they should be represented. It intends to provide a framework for harmonisation of disparate information systems and to facilitate the collection of data elements crucial for public health, administration, quality assurance, and research needs.

2) National Emergency Medical Services Information System (NEMSIS): it is a U.S. national effort to standardise the data collected by EMS agencies, in order to help states submit consistent data to a national EMS database [15].

3) National Information Exchange Model (NIEM): it is a baseline set of reusable XML Schema components for building Information Exchange Package Documentation (IEPD) [16]. One of the NIEM Domain Schemas is for Emergency Management. The NIEM Conformant Schemas (code lists and adaptations of external standards) include, among others, EDXL-RM, EDXL-CAP, EDXL-DE, and EDXL-HAVE.

D. Summary

The detailed analysis of the relevant standards revealed that the OASIS EDXL-based knowledge models seem as the most suitable to address the DSS needs presented in Section II through the user-driven scenarios and subsequent analysis. EDXL can be considered as the most complete approach, being widely used by various stakeholders of the emergency management community. It should be pointed out, however, that the existing EDXL-based knowledge elements are designed with the support for XML notation, which is a purely syntactic way to describe knowledge concepts. Thus, the role of semantic technology introduced by this research is firstly to ensure the common operational and organisational understanding of the transferred knowledge aspects among various actors involved in the management of emergency situation in the process of information sharing. The second function of semantics is to enrich the information communicated among various actors, with additional inferred knowledge, which will provide a better picture of the situation context and thus support more efficient decision making.

The proposed knowledge modelling framework is discussed in the following section.

IV. Proposed Knowledge Models and Tools

The requirements for the knowledge management framework discussed in Section II, as well as the analysis of the relevant scenarios, have been used as a basis to identify the needs for the required knowledge models and the semantic extensions. The first step was the analysis of abstracted use cases of the scenarios' context, in order to identify the potential of the knowledge management system to support the scenarios' objectives and the DSS. Next, the particular decision support means that are needed for the system have been identified, along with the information on the input knowledge required and the expected output results to be modelled and stored. The EDXL-based models have been selected as the central knowledge models to utilise. Finally, the knowledge elements (inputs, outputs, decisions) have been classified according to their belonging to the existing introduced EDXL-based models, as well as according to the design and the run-time nature of knowledge assets. The dimensions of the knowledge assets, their nature (design/run-time) and the format of the knowledge content (e.g. document, image, sensors measurements, etc.) determine the structure and the knowledge representation language and knowledge management infrastructure to be developed.

As a result, a set of conceptual models has been identified for the support of the decision making process (see Fig. 2). The main models of the proposed framework are: User, Context, SocialNet, Expert Knowledge, and Domain Models. Each conceptual model focuses on a single aspect of relevant knowledge, however, all models are connected to each other, e.g., a property that one model refers to and uses, may belong to another model. The models are further discussed below.

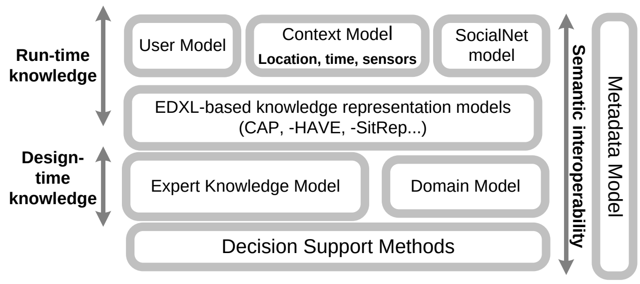

Fig.2.The main models of the proposed conceptual modelling framework

A. User Model

The notion of the Actor is important in order to tackle the identified requirements, therefore the User Model represents various Actors involved in emergency management. The information about actors may include various aspects, such as the Role in the process of incident management (see the five spaces/phases of Section II), as well as the available resources and services provided by the Actor (e.g., equipment of the transporter or capabilities of the bystander). The user Role may facilitate the information representation views based on the task in hand and the level of expertise. The description of resources and capabilities will help to match the needs to the available services. Moreover, the patient as an Actor is placed in the central role for the medical services delivery and related information flows. Accordingly, several user Roles are identified. USER has ROLE – Victim; PSAP; First Responder; Transporter; Incident Field Commander; Emergency operations Center; Bystander; First receiver. User's Role may presume certain access rights and security measures. USER is represented by PROFILE (# has Profile). PROFILE may describe available RESOURCES and capabilities, i.e., provided SERVICES which can be advertised and discovered by the relevant functions of the DSS. In particular, Patient's PROFILE may describe triage measurements, vital parameters, and other necessary and personal data such as contact and medical information, to facilitate the treatment and follow up task towards the awareness, safety, and comfort of the patient (see "Transmittable patient status parameters" in Section II).

The EDXL-HAVE model provides extensive XML-based means to describe various users' profiles of first receiver (ambulance, hospital) and EDXL-TEP is sufficient to represent patient related information. In addition, the Emergency Care Minimum Dataset [17] can ensure that in particular patient treatment related information is properly defined. However, extensions are required to represent other actors involved in the incident management, as well as their roles (and tasks). From the semantics point of view, many RDF/OWL ontologies have been developed for user modelling, with the most prominent and widely accepted developments delivered by the research community being the General User Model Ontology (GUMO) and the Friend of a Friend (FOAF) ontology.

B. Context Model

While Context is a broad term and may contain various types of information, it is approached here in a pragmatic and practical way, taking on board the most critical information identified through the use-cases and the scenarios, such as "Location" and "Time". In addition, some scenarios may require predictive information, such as "meteorological" and "environmental" conditions, which may influence the development of an emergency situation (e.g., to prepare the necessary resources for the incident close to the river in Scenario 1 of Section II). Some projected data and the results of simulations (e.g., estimation on resources capacity) can also be addressed by this model. Moreover, for the sake of simplicity, any information obtained from sensors (such as sensors' readings regarding victim's vital signals) is considered as part of the Context knowledge model.

The EDXL-DE model provides the means to describe the location of an incident (targetArea), while current and predicted weather conditions (weatherEffects) are defined by EDXL-SitRep. The incident-related projected information is partly defined by the IncidentDecisionSupportInformation complex type of EDXL-SitRep, containing the descriptive information about the projected incident activity, critical resources, scope, status of the response, and cost estimates.

The envisioned extensions to the existing knowledge representations may relate to the representation of sensors' readings, definition of relative locations (e.g., train, floorplan of the building, junction on motorway, etc.), as well as to the modelling of any additional projected information (e.g., expected capacity and demand on resources). In the emergency context, various types of locations are involved, such as the positions of responders, vehicles, patients, bystanders, equipment, etc., which are critical to achieve the fastest possible response.

As a starting point to extend syntactic EDXL knowledge elements to represent location, the spatial model defined in FP6-Amigo[1] and extended in FP7-SmartProducts[2] projects are considered. Locations can be represented either in absolute terms (by x, y, z coordinates or by latitude/longitude pairs) or even relatively to some other location (e.g., "between junctions 13 and 14 of the M1 road"). For these, two subclasses of the generic type #Location, i.e., #AbsoluteLocation and #RelativeLocation, can be used. The #RelativeLocation is expressed as #Offset in relation to some #ReferenceSystem, which can be a 3D coordinate system defined by its axis vectors with a center in some other #Location or attached to some #SpatialObject or #SpaceRegion. In addition, the Open Linked Data datasets, such as DBpedia vocabularies to represent the location and GeoNames[3], which provides RDF descriptions of more than 7,500,000 geographical features worldwide, can be utilised. The vocabulary provided by the Time Mode[4] can be utilised to represent Time information. The ontology allows relations between time instants and intervals to be expressed, as well as information about durations, date-time information and time zones. If required, the Environmental and Meteorological data including the weather information can be modelled by a combination of several ontological approaches, such as Time and Location ontologies discussed earlier, while the sensors measurements can be represented by the Semantic Sensor Network Ontology [18].

C. SocialNet Model

The emerging social media and in general the so-called Web 2.0 technologies have a great impact on the practices and applications used in the emergency management tasks and they form an extensive area of research by themselves [19]. The objective, in this work, is to test how the input shared by bystanders through social media (location and overall description of the incident situation from a smartphone) in the form of text and/or image can be taken into account as an additional source of information to facilitate the delivery of medical emergency services. Concepts defined by the EDXL-SitRep knowledge models (e.g., location, number of injured persons, etc.) can be also used to describe the information provided by bystanders; nevertheless, it is probably a good practice to keep this information separately. From the accountability point of view, the "Social_Tag" can be introduced to mark the information coming from social media. The most prominent and widely used approach for the integration of online community information is the Semantically-Interlinked Online Communities (SIOC) ontology which is commonly used in conjunction with the FOAF vocabulary for expressing personal profile and social networking information.

D. Domain Model

This model extends generic models, such as User and Context, with domain specific information; it may contain for example the taxonomies of an emergency event. During the emergency response, the type of the emergency event may help deciding the type of response to mobilise, i.e., response procedures and resources to be deployed. Another example of domain specific knowledge can be the information about the health impact on a particular emergency event. The incident related knowledge can be extensively defined using EDXL-CAP and EDXL-SitRep knowledge elements. The semantic interoperability and enrichment of the incident-related concept is one aspect that can be addressed using domain specific ontologies.

Unfortunately, as previously indicated, very few ontologies published in research papers are formally represented and publicly accessible, and to a large extent they are in the form of database schemas. There is also little effort on domain ontologies that support specifically the provision of health services in the emergency situation. It is observed also that the domain is lacking clear applications to leverage domain specific ontologies for additional knowledge acquisition. Thus, the considered approach is to design a small scale application-specific ontology for the knowledge acquisition to support in particular the delivery of medical services. General purpose Linked Data datasets, such as DBpedia and Freebase, can be utilised to support information interoperability aspects.

E. Expert Knowledge Model

The Expert Knowledge model presents the information related to various procedures and processes that are necessary to be performed in case of disaster management. When first responders arrive at a mass-incident, they immediately need to deal with a variety of victims with various and diverse needs. It can be challenging to remember all procedures under stress and time pressure, therefore a pre-defined list (i.e., taxonomy or process model) of common treatment needs would be beneficial if kept by the system. In addition, the level of expertise of the first responder could vary (medical vs. bystander), therefore depending on the profile of the user, various levels and types of content (e.g., triage instructions) can be presented. The expert knowledge (rules, instructions, processes, etc.) can be linked to knowledge about emergency event types, specific events, victim severity, task in hand, and role of the user. The RDF/OWL based task taxonomy to facilitate the process of fetching of required expert knowledge (e.g., pop-up into UI) is considered. The proposed taxonomies can facilitate also the linking of historical data, lessons learnt, and previous decisions made. Moreover, the same approach can be used to implement explanation mechanisms, for the decision makers to trust the intelligence of the system by comprehending how the decision was made and what action should be performed as a result.

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[2] http://www.smartproducts-project.eu/
[3] http://dbpedia.org/ontology/location, http://www.geonames.org/
[4] http://www.w3.org/TR/2006/WD-owl-time-20060927/

F. Metadata Model

The Metadata model aims at providing the knowledge about other knowledge i.e. content. Content can exist in various formats such as documents, simulation models, sensors' readings, Web pages, social media content, visualisations, images, maps, sketches, etc., being structured and/or unstructured. Thus, a metadata model is necessary to perform the content management functions to support DSS tasks. Metadata may contain technical elements such as ContentID, UploadTime, Uploader, and URL as well as ones such as Tag, Description, and Category, which may restrict the content search space and facilitate the understanding of the semantics of the content. Both annotation types aim at supporting a more efficient information search, presentation, and visualisation.

To summarise, the following Open Linked Data datasets are utilised to facilitate the knowledge management tasks towards the knowledge-level interoperability and the enrichment of EDXL knowledge elements: DBpedia provides an RDF view of the Wikipedia content. It can be used via SPARQL [20] using several existing end-points. Freebase offers cross-domain community-generated content complementary to DBpedia. Geonames is an open-license geographical database that publishes Linked Data about 8 million locations. LinkedGeoData provides the data from the OpenStreetMap project, which includes information about more than 350 million spatial features. Locations in Geonames and LinkedGeoData are interlinked with corresponding locations in DBpedia. Furthermore, the set of open source technologies such as TextRazor (https://www.textrazor.com/), OpenCalais (http://new.opencalais.com/), JSON-LD (http://json-ld.org/index.html) and ElasticSearch (https://www.elastic.co/) are utilised to support information extraction, semantic annotation, indexing and search. Efforts focusing on the disaster management domain, such as the work of the CODATA Task group, will be carefully assessed in the scope of future development [21].

V. Conclusion

This paper has presented an emergency management knowledge representation framework which serves as a guideline for the implementation stage. It is expected that the framework will be updated during the upcoming research and development phase of the work. The aim of this research is to highlight and explore the synergy of existing widely accepted emergency management standards like EDXL and the evolving Open Linked Data dataset as control vocabularies and a way to enrich the knowledge concept towards an efficient communication of heterogeneous data in emergency situations and an effective disaster management. Linked Data technology can facilitate interoperability and improve shared understanding of key information elements; it enables links to be set between items in different and heterogeneous data sources and, therefore, combines these sources into a single global data space. The use of Web standards and a common data model make it possible to implement applications that operate over the complete data space.

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